III. "Contributions to the Physiology of Batrachian Lymph-Hearts." By JOHN PRIESTLEY, Assistant-Lecturer in Physiology in Owens College, Manchester. (From the Physiological Laboratory of Owens College.) Communicated by Professor ARTHUR GAMGEE, F.R.S. Received January 31, 1878.

The following paper contains a summary of observations made in order to obtain data for a comparison between the blood-heart and lymph-hearts of frogs. The comparison is to include the actions of electrical currents and of the so-called cardiac drugs, atropia, physostigma, muscaria, antiar, &c.; but this paper will treat only of the electrical portion of the work.

Before proceeding to the collection of facts especially fitted for comparison, the normal anatomical and physiological arrangements of the lymph-hearts were examined; and, as the result of this examination, the author is able to confirm the discoveries of previous observers in the following points:—

1. The lymph-hearts of *Rana temporaria* are muscular sacs, whose walls consist of branched, anastomotic, transversely striated muscular fibres, abundantly nucleated (Leydig,* Waldeyer†). A cursory examination failed to discover any ganglionic nervous elements among the muscular fibres themselves, their absence having already been noticed by Volkmann‡ and Waldeyer;§ but nerve-ganglia are said to be found near the hearts, in their connective tissue environment (Waldeyer).‖

2. The lymph-hearts beat with a mean rate of 60–70 a minute, and are independent in their rhythm of one another, of the blood-heart, and of the respiratory movements (J. Müller)¶. But the normal pulsation is not quite regular, being occasionally broken by sudden pauses or by periods of increased rapidity of beat. These interruptions seem to be partly due to movements of the animal, but in part to hitherto undefined causes.

3. The hearts receive nerve-fibres from the spinal cord, which descend in the second and tenth spinal nerves respectively for the anterior and posterior pairs of hearts (Volkmann,** Eckhard,†† Schiff ‡‡).

* Leydig, Lehrbuch der Histologie, 1857.

† Waldeyer, Henle u. Pfeufer's Zeitsch. für rat. Med., 3rd Series, vol. xxi, 1864.

‡ Volkmann, Müller's Archiv, 1844, p. 419.

§ Waldeyer, *loc. cit.* ‖ Waldeyer, *loc. cit.*

¶ J. Müller, Philosophical Transactions of Roy. Soc. London, 1833. Poggendorff's Annalen, 1832. Müller's Archiv, 1834.

** Volkmann, *loc. cit.*

†† Eckhard, Henle u. Pfeufer's Zeitsch., 1849, vol. viii.

‡‡ Schiff, Henle u. Pfeufer's Zeitsch., 1850, vol. ix

4. The normal rhythm of the heart is dependent on the soundness of certain regions of the spinal cord, viz., for the anterior pair, of the region opposite the 3rd vertebral body (Volkmann*), for the posterior pair, of the region opposite the 6th. This statement is a correction of the view commonly held in respect of the spinal region concerned in the rhythm of the posterior hearts; for all previous observers seem to have followed Volkmann in saying that the region of the 8th vertebral body is that implicated.

If these regions are injured, or if the nerves proceeding from them to the hearts are intercepted, either the hearts are brought to rest permanently, or their natural pulsation is disorganised and reduced for a long time to more or less irregular fluttering. These spinal centres seem capable of inhibition by strong sensory (afferent) stimuli, even in the absence of the encephalon.

5. The natural pulsation of the lymph-hearts is constantly controlled from an encephalic inhibitory centre in the optic lobes, separation from which is, therefore, at once followed by increased rate of beat (Suslowa.)† This inhibitory centre is said by Goltz ‡ to be roused into stronger action by powerful mechanical stimuli proceeding along the vagi from the heart, or proceeding from the abdominal viscera in the *Klopfversuch.*

6. The disorderly contractions that follow division of the lymph-cardiac spinal nerves may give place to a regular pulsation (Eckhard,§ Schiff,|| Heidenhain ¶). The restoration does not usually take place until after many days, but when established, the rhythmical beating is independent of the spinal cord, not ceasing, like the pulse of normal lymph-hearts, when the central nervous system is destroyed (Goltz,** Waldeyer††). The cause of these movements is not yet fully understood; but the movements themselves are abolished by local or general application of curare in solution.

Action of Electrical Currents on the Lymph-Hearts of Frogs.

A complete description of the action of electrical currents on the lymph-cardiac mechanism includes the action of induced currents and of constant currents. The latter were generated by Grove's or Daniell's elements, the former by a Du Bois' induction coil. The portions of the lymph-cardiac apparatus tested were brought into the circuit by appli-

* Volkmann, *loc. cit.*

† Suslowa, Centralblatt f. med. Wis. 1867, p. 832. Henle u. Pfeufer's Zeitsch., 1868.

‡ Goltz, Centralblatt f. med. Wis. 1863, p. 17; p. 497. Ibidem, 1864, p. 691.

§ Eckhard, *loc. cit.* || Schiff, *loc. cit.*

¶ Heidenhain, Disquisitiones de nervis cordis, etc. Berlin. 1854. (Dissertation.)

** Goltz, *loc. cit.* †† Waldeyer, *loc. cit.*

cation either of common non-polarizable electrodes or of electrodes of platinum wire.

I.—Action of Induced Interrupted Currents.

a. On the lymph-cardiac muscle detached from its nerve (as an ordinary voluntary muscle may be detached) *by means of curare.*—The electrodes were laid on the back after the removal of the skin, as close to the posterior lymph-hearts as possible. Under these circumstances the lymph-hearts behave exactly like the surrounding striated muscles, not differing from them to any remarkable extent, either in minimal stimulus or in mode of contraction.

b. On the lymph-cardiac spinal nerves after anatomical separation from the lymph-cardiac spinal centre.—The spine and cord were snipped through at the level of the 7th vertebra, and one non-polarisable electrode was applied to the exposed lower end of the cord; while the back of the 8th vertebral arch was removed, and the other electrode, well moistened with normal saline solution, was introduced at the window so made. Or a pair of platinum electrodes were slipped beneath the abdominal branch of the tenth spinal nerve running to one of the posterior hearts, the heart having previously been brought to rest by division of the same branch near the coccygeal foramen. Under these circumstances the lymph-cardiac muscle-nerve preparation behaves like any ordinary muscle-nerve preparation, except that it possesses a much larger minimal stimulus.

If contact between nerves and electrodes were not very perfect in the spinal canal, or if currents near the minimal stimulating point were employed, the usual firm tetanus of the lymph-hearts became broken into a series of explosive, beat-like, or twitching movements. But, under similar conditions, ordinary muscle-nerve preparations re-act in a similar manner.

c. On the lymph-cardiac spinal centre separated from the encephalic inhibitory centre.—The frog was decapitated, and all the spinal nerves were divided except the tenth. Windows were cut into the back of the spinal canal, opposite the 5th and 8th vertebræ, and into the windows well-moistened non-polarizable electrodes were pushed. Or the spinal canal was opened from the 5th to the 8th vertebræ, and platinum electrodes slipped beneath the cord or made to touch the cord lightly one at each side at the level of the 6th vertebra. Under these circumstances slight currents, strong enough to contract at the same time the ilio-coccygeal muscles, slowed the lymph-hearts; stronger currents inhibited the hearts in diastole, and still stronger currents caused a tetanic systole of the hearts like the simultaneous tetanus induced in neighbouring nerve-supplied muscles. The strong currents sufficient to cause in this manner prolonged diastolic inhibition of lymph-hearts still dependent on their spinal

centres, are also of a strength to cause powerful tetanus of the same lymph-hearts when applied to their nerves in the spinal canal, as described under *b*.

It should be noticed that the same explosive, pulse-like movements occurred here as under *b*, when the conditions were similar.

This action of the interrupted induced current on the lymph-cardiac spinal centres is not abolished by the local or systemic exhibition of solutions of atropia.

II. Action of Constant Currents.

The currents were applied to the structures tested by means of non-polarizable electrodes of ordinary form.

a. On the lymph-hearts brought to rest by separation from their spinal centres.—After operations involving extensive bleeding, separation from their spinal centres is, in nearly all cases, followed by permanent stand-still of the dependent hearts. In the experiments described the frogs were decapitated and eviscerated, all the spinal nerves except the tenth were divided, and the thighs amputated in order to obviate any disturbing muscular movements. The electrodes were applied to the base of the back near the heart to be examined, sometimes in a direction laterally across the heart, and sometimes in the longitudinal axis of the heart; or the heart was carefully excised with its surrounding connective tissue, placed upon the clay of one electrode, and lightly touched with the point of the other. In the latter way of experimenting no attention was paid to the relation of the current to the axes of the heart, on account of the small size of the organ in *R. temporaria*. Under these circumstances with various strengths of battery from 2–3 small Daniell's cells to 16–18 Grove's, nothing but ordinary opening and closing contractions could be caused.

b. On the lymph-hearts still beating in normal dependence on their spinal centres.—The electrodes were placed either on the lateral or the longitudinal axes of the hearts, as in *a*. Under these circumstances, in whatever direction the current flows, the pulsation of the hearts is hampered or inhibited, the hampering affecting rather the depth than the frequency of the beats.

c. On the lymph-cardiac spinal centres.—The well-softened electrodes were pushed in at windows opening into the spinal canal through the 5th and 7th or 8th vertebral arches, after the frog had been decapitated and the spinal nerves, except the tenth, all divided; or one electrode was placed on the upper end of the cord exposed in decapitation, while the other was placed in the window through the lower vertebral arch.

a. On the acting spinal centre.—Different results were obtained according to the direction and strength of the current, varying from complete stand-still in diastole to pulsation much more rapid than normal; but all seem capable of explanation by the aid of the known laws of

electrotonus, the known effect on the neutral line of varying battery power, and the assumption of a stimulating influence of the current *per se*, which may counteract the depressing effects of the anelectrotonic state.

β. On the spinal centre exhausted by the effects of operative procedure, exposure, etc. Restoration to activity follows the passage up or down the cord of a current for 1–2 Grove's cells. Such restoration the author does not think it possible to attribute in every case to the presence of favouring katelectrotonus; it must be set down to a stimulation by the current *per se*.

γ. On the spinal centres of hearts inhibited by stimulating with strong NaCl solutions the upper exposed end of the cord of a decapitated frog. The electrodes were inserted into the spinal canal through windows in the 5th and 7th or 8th vertebral arches. Under these circumstances the hearts cannot be set going by passing a current through the spinal centres, unless, perhaps, when the current is very strong (from 5–6 Grove's); and then only when the anode is *above* the spinal centres, and, therefore, in a position to intercept the descending inhibitory stimulus by means of the anelectrotonic state which it induces.

IV. "On the Structure of the Stylasteridæ, a Family of the Hydroid Stony Corals." By H. N. Moseley, F.R.S., Fellow of Exeter College, Oxford, late Naturalist on board H.M.S. 'Challenger.' Received January 22, 1878.

[For "Preliminary Note," see Proceedings, vol. xxv. p. 93.]

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Transactions.

Basel:—Schweizerische Naturforschende Gesellschaft. Verhandlungen. 59 Jahresversammlung. 8vo. 1877. The Society.

Berlin:—Königliche Akademie der Wissenschaften. Abhandlungen aus dem Jahre 1876. 4to. 1877. The Academy.

Bern:—Naturforschende Gesellschaft. Mittheilungen aus dem Jahre 1876. Nr. 906–922. 8vo. 1877. The Society.

Berwickshire Naturalists' Club. Proceedings. Vol. VIII. No. 1. 8vo. 1877. The Club.

Bombay Branch of the Royal Asiatic Society. Journal. Vol. XII. No. 34. 8vo. 1877. The Society.

Boston [U.S.]:—American Academy of Arts and Sciences. Proceedings. Vol. XIII. Part I. 8vo. 1877. The Academy.